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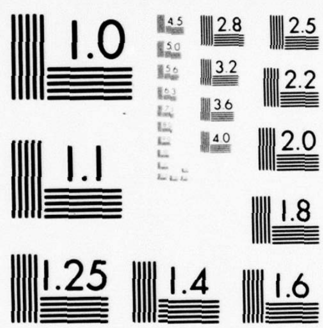


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# PERFORMANCE AND EVALUATION OF CONCEPTS AND DEVICES FOR HEAT RECLAMATION FROM AIR CONDITIONERS, HEAT PUMPS, AND REFRIGERATION EQUIPMENT


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A heat recovery system is described which uses air conditioner or heat pump waste heat for domestic water heating. Current commercial units and field test data are detailed with economic guidelines to aid in choice of a unit. This report enables the reader to determine the cost effectiveness of having such a unit installed. Safety, product warranty, and city and state coding restrictions are discussed. The current and future testing and demonstration plans are cited for the unit.

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TABLE OF CONTENTS

## I. ABSTRACT

A heat recovery system is described which uses air conditioner or heat pump waste heat for domestic water heating. Current commercial units and field test data are detailed with economic guidelines to aid in choice of a unit. This report enables the reader to determine the cost effectiveness of having such a unit installed. Safety, product warranty, and city and state coding restrictions are discussed. The current and future testing and demonstration plans are cited for the unit.

## II. INTRODUCTION

The concept described is that of recovering the waste rejected heat from central air conditioners for use in domestic water heating. In this concept the condensation of refrigerant is still done by rejecting heat to outside air; however, the desuperheating of the refrigerant at higher temperatures is used to heat water within the residence.

In the same manner the heat recovery system (HRS) may be used with a heat pump above the balance point when it is operating in the heating mode. In both air conditioners and heat pumps the HRS is placed between the compressor and the condenser.

A similar system could be applied to residential refrigeration systems, however, a study done by A. D. Little, Inc.,[1] indicates the areas of concern: (1) longer periods to payback, (2) uncertainties in the reliability of the system and, (3) uncertainties of the impact on the product warranty of the refrigerator. No testing has been done on this concept and further consideration is not given here.

The residential HRS system is a lower limit to payback on initial investment. Commercial HRS systems have invariably better payback periods than do residential systems.

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[1]Design, Development and Demonstration of a Promising Integrated Appliance, A. D. Little, Inc., W. D. Lee, Project Manager, performed for ERDA September 1977.

## III. PRECEDENT AND BASIC DESIGN

Initial development of heat recovery units for residential and small commercial use was performed by Florida Power and Light in the early 1960s. A system was designed which is being marketed today, shown in Figure 1, in which water is circulated from the storage hot water tank to a heat exchanger placed between the compressor and condenser of the air-cooled air conditioner. During the operation of the compressor, if the water temperature in the storage tank is below the upper limit, the circulation pump is activated and heat is extracted from the refrigerant, thereby providing water heating. Typically, the refrigerant enters the water heat exchanger at 200-250$^{o}$F, providing ample temperature for achieving useful water temperatures for domestic purposes (130-140$^{o}$F).

Another basic design consists of a bayonet-type exchanger in the water heater which is fed by refrigerant circulated from the compressor, eliminating the water pump. This design is no longer being marketed, therefore no further consideration is given to this unit.

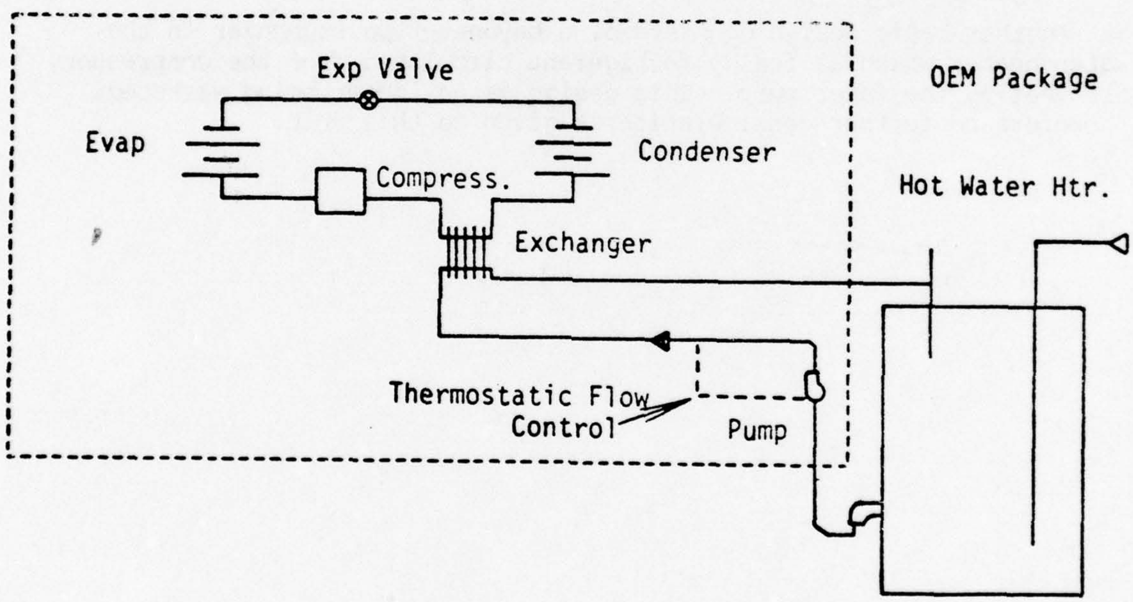


Figure 1. Heat Recovery Water Heating System

## IV. METHODS OF ENERGY SAVINGS

### A. Heat Recovered from Refrigerant

In a refrigeration cycle, which is the basic cycle used in a refrigerator, air conditioner and heat pump, high temperature refrigerant gas (200-250°F) enters a condensing unit where it exchanges heat with an air or water stream, depending on the condenser design. This heat is normally lost except during the heating modes of a heat pump where it is utilized for space heating.

#### A.1. Cooling Mode

Typically an air conditioning system with an air-cooled condenser rejects about 16,000 to 17,000 Btu/hr for each ton of cooling capacity. Of this amount 3000 to 5000 Btu/hr of superheat can easily be utilized for water heating. A heat exchanger is installed in the hot gas line between the compressor and the condenser of the air conditioner. Water from the cold water supply to the water heater is circulated through the heat exchanger by a circulating pump. In practice removal of heat from the refrigerant is limited to the superheated region, since the maximum amount of water heated to final utilization temperature can be produced. Furthermore excessive heat removal in the auxiliary heat exchanger causes condensation and results in the formation of subcooled refrigerant in the condensor. This in turn causes choking in the capillary expansion process.

#### A.2. Heating Mode

During the heating mode of a heat pump since the coefficient of performance[1] is generally higher than 2, each Btu of electrical energy input can generate two or more Btu's of heat which can be utilized for space heating as well as water heating. The mechanism of heat extraction is identical to that of a refrigeration cycle.

### B. Compressor Efficiency Improvement

Removal of superheat from the refrigerant causes a reduction in the refrigerant loop temperature which in turn results in lower compressor pressure head. Because of this reduction in head pressure, the compressor operates more efficiently and the electrical demand of the compressor is reduced. Furthermore, lower temperature of the refrigerant loop causes greater temperature driving force in the evaporator which

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[1] $$\text{Coefficient of performance} = \frac{\text{heat obtained}}{\text{electrical energy required}}$$

in turn reduces the operation time of the compressor for a given cooling load. The effect of the refrigerant inlet temperature to condenser on the energy efficiency ratio EER (ratio of cooling capacity in Btu/hr to total unit input in watts) of an air conditioner or heat pump for three different outside temperatures is presented in Figure 2. It should be noted that this figure is the result of a computer simulation of an air conditioner/heat pump model (for detailed description refer to A. D. Little report). Normally, even with the HRS, the refrigerant gas inlet temperature to the condenser would never be less than 125°F. The steep portions of the curve represent abnormal operation and may be ignored. As is shown, a drop in the refrigerant inlet temperature to the condenser causes an increase in EER. From an empirical standpoint most manufacturers of heat recovery units claim an efficiency improvement equivalent to 1 to 25% reduction in total energy consumption of compressor.

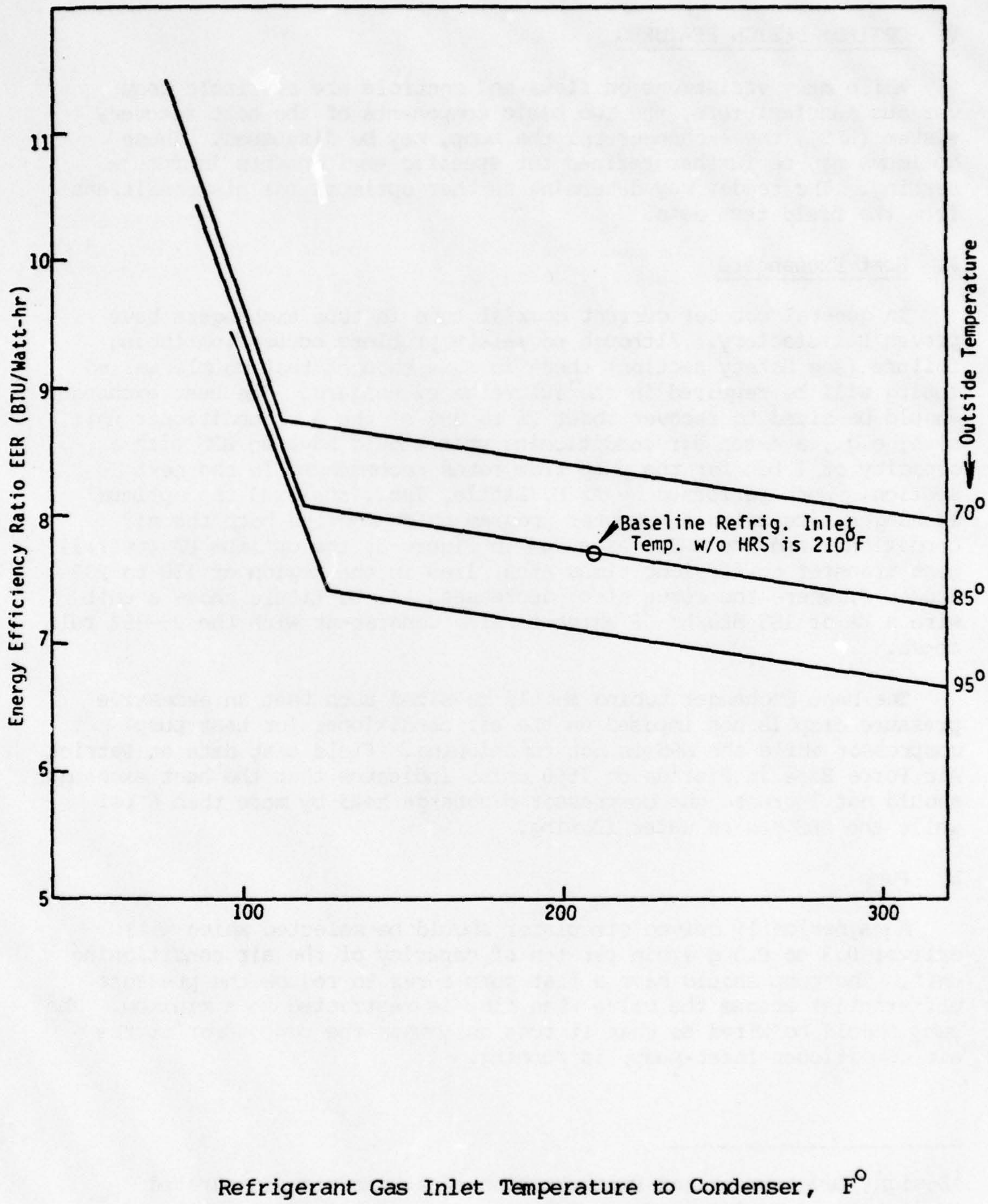


Figure 2. Energy Efficiency Ratio vs. Refrigerant Inlet Temperature to Condenser.

## V. OPTIMUM DESIGN FEATURES

While many variations on flows and controls are available from various manufacturers, the two basic components of the heat recovery system (HRS), the exchanger and the pump, may be discussed. These optimums may be further refined for specific environments in future testing. The reader may determine further optimums for his conditions from the field test data.

### A. Heat Exchangers

In general counter current coaxial tube in tube exchangers have proven satisfactory. Although no safety problems occur from tubing failure (see Safety section) there is some thought that double walled tubing will be required in the future as exchangers. The heat exchanger should be sized to recover about 25 to 35% of the air conditioner unit size; e.g., a 4-ton air conditioning unit should have an HRS with a capacity of 1 ton for the pump flow rates recommended in the next section. Work performed by A. D. Little, Inc.,[1] analyzed the optimum exchanger size using a computer program which modeled both the air conditioner and the HRS. As shown in Figure 3, the optimum UA (overall heat transfer coefficient times area) lies in the region of 150 to 200 Btu/hr $^{o}$F, where the curve slope decreases. A. D. Little chose a unit with a UA of 165 Btu/hr $^{o}$F which is also consistent with the 25-35% rule above.

The heat exchanger tubing should be sized such that an excessive pressure drop is not imposed on the air conditioner (or heat pump) compressor while the HRS is not functioning. Field test data at Patrick Air Force Base in Florida on 1500 units indicates that the heat exchanger should not increase the compressor discharge head by more than 6 psi while the HRS has no water flowing.

### B. Pump

A magnetically driven circulator should be selected which will deliver 0.3 to 0.5 gal/min per ton of capacity of the air conditioning unit. The pump should have a flat pump curve to reduce the pressure differential across the valve when flow is restricted to a minimum. The pump should be wired so that it runs only when the compressor of the air conditioner (heat pump) is running.

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[1] Design, Development and Demonstration of a Promising Integrated Applicance, A.D. Little Inc., W.D. Lee, program manager, performed for ERDA, September 1977.

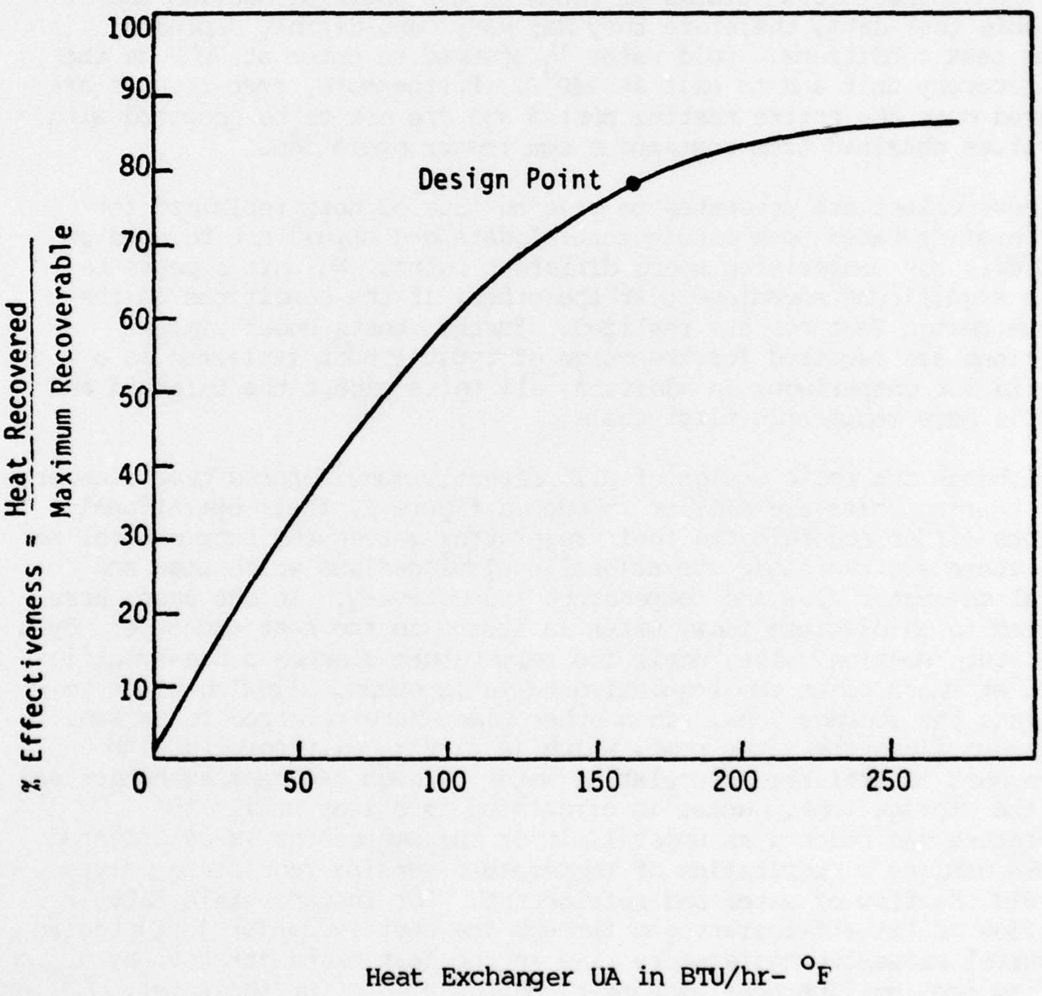


Figure 3. Variation of Effectiveness of Heat Transfer Area

## VI. COMMERCIAL UNITS AND DESIGN DIFFERENCES

A summary of the commercially available units and their manufacturers is given in Table 1. Table 2 presents a number of significant features of these units.

The cost of each of the units in Table 2 should not vary appreciably from the \$300 - \$400 range for a heat recovery unit installed on a 3-ton air conditioner. In Table 2 typical Btu/ton-hr reclaimed refer to the amount of heat which is recovered and utilized for water heating per ton capacity of air conditioning per hour. These figures are obtained from the manufacturers' claims on rates of hot water production and/or available test data, therefore they may vary considerably depending on the test conditions. Cold water is assumed to enter at 70$^{\circ}$F to the heat recovery unit and to exit at 140$^{\circ}$F. Furthermore, test results are averaged over the entire testing period and are not to be compared with the values obtained from continuous compressor operation.

These values are presented to give an idea of heat reclaimed for water heating based upon manufacturers' data and should not be used as a criteria for comparision among different units. No unit appears to have a significant advantage over the other, if the conditions in the Optimum Design Features are realized. Further tests under similar conditions are required for the usage of typical heat reclaimed as a criteria for comparison. In addition, all units except the Halstead and Mitchell have comparable first costs.

Although the basic design of all presently manufactured heat recovery-water heating units are similar to one in Figure 1, their operational concepts differ according to their regulating valves and pump control set ups. There are two basic operational control designs which time and control the water flow and temperature respectively. In one case, here referred to as discrete flow, water is stored in the heat exchanger, by a temperature sensing valve, until its temperature reaches a pre-specified limit, at which point the regulating valve is opened allowing water to flow into the storage tank. In another case, here referred to as semi-continuous flow, the water pump, which is electrically coupled with compressor, is activated circulating water through the heat exchanger and into the storage tank. Water is circulated in a loop until its temperature has reached an upper limit or the compressor is deactivated. In some designs a combination of temperature sensing regulating valves controls the flow of water and refrigerant. For instance in a Marvair unit flow of hot refrigerant gas through the heat exchanger is regulated to control excessive temperature rise in the heat exchanger thereby limiting scaling. The heat exchanger configurations for the water circulating systems use a tube-in-tube, tube-on-tube, or tube-in-shell configuration. Refrigerant and water are separated by either single wall, double wall or bonding wall. In some designs water flows in the

TABLE 1

COMMERCIALLY AVAILABLE HEAT RECOVERY-
WATER HEATING UNITS

| | Unit | Manufacturer | Address |
|---|---|---|---|
| 1. | ECU | Energy Conservation Unlimited | Longwood, Florida 32750 |
| 2. | HOT-TAP | Energy Conservation Unlimited-Promoted by Arizona Public Service Co. | Phoenix, Arizona 85000 |
| 3. | Lectra Saver | Growth Systems Technology Inds., Inc. | Tampa, Florida 33600 |
| 4. | H&M HRU* | Halstead & Mitchell | Scottsboro, Florida |
| 5. | Weather King HRU | Weather King, Inc. | Orlando, Florida 32800 |
| 6. | Econ-O-Mate | Sun-Econ, Inc. | Ballston Lake, NY 12019 |
| 7. | Hot-Shot | Carrier | Syracuse, NY 13200 |
| 8. | Heat Grabber | Lynn-Aire Products, Inc. | Decatur, Georgia 30030 |
| 9. | Heat Gainer | **W. L. Jackson Mfg. Co., Inc. | Chattanooga, TE 37400 |
| 10. | A/C and H.P. Water Heater | Marvair Co. | Coredele, Georgia 31015 |

* HRU (Heat Recovery Unit)
** No Longer in Production

TABLE 2

COMPARISON OF CURRENTLY AVAILABLE HRS UNITS

| UNIT | CONFIGURATION | PRESENTLY AVAIL FROM | SAFETY | OPERATIONAL PROBLEMS | TYPICAL BTU/TON-HR RECLAIMED | INITIAL COST |
|---|---|---|---|---|---|---|
| Econ-O-Mate | Tube-in-shell | Retrofit-OEM | Single wall separates water from ref. water on the outside. | Convoluted design, minimal scaling, continuous flow(CF)[1] | 3600-7600 | $300-800 |
| ECU | Tube-in-tube helix | Retrofit | Double wall separates water from ref. Ref. on the outside | Convoluted design, minimal scaling. Discrete Flow (DF)[2] | 2900-4100 | $400-600 |
| Friedrich | Tube-to-tube | Retrofit-OEM | Double wall | Scaling | 1700 | $350 |
| H&M HRU | Tube-in-tube | Retrofit | Single wall Ref. on the outside | Heat exchanger ends removable for cleaning CF | 3300 Btuh/comp. H.P. | $600-900 |
| Heat Grabber | Tube-in-tube | Retrofit | Single wall. Ref. on the outside | Heat exchanger ends removable for cleaning CF | 5000 | $300 |
| Hot Shot | Tube-in-tube | Retrofit-OEM | Double wall | Scaling a problem CF | 2000 | $300 |
| Hot Tap | Tube-in-tube helix | Retrofit | Single wall. Ref. on outside | Convoluted design minimal scaling DF | 2900-4100 | $300-500 |
| Lectra Saver | Tube-in-tube | Retrofit | Single wall. Ref. on outside | Scaling a problem CF | 3000-5000 | $300 |
| Marvair | Tube-on-tube | Retrofit-OEM | Side by side tubing bonding wall | Scaling a problem CF | N.A. | $300 |
| Weather King | Tube-in-tube | Retrofit-OEM | Single wall. Ref outside | Scaling a problem DF | 3700 | $350 |

[1] Semi-continuous flow while compressor is on

[2] Discrete flow design

inner tube and refrigerant in the outer one. This design allows the refrigerant to escape to atmosphere in case of an external tube rupture. If the water is on the outside, however, refrigerant tube failure causes high pressure refrigerant to escape into the potable water. The placement of the refrigerant tube is not crucial because, as discussed in the Safety Section, mixing of refrigerant with water does not seem to cause any health problems.

One of the basic concerns in design is scaling which always exists with heat exchangers. The severity depends on the quality of water (soft or hard), and the water turbulence or mixing patterns. Convoluted wall design of heat exchanger is used in some heat recovery units as a means of enhancing flow turbulence thereby minimizing scale formation. Other designs take advantage of removable exchanger ends for cleaning purposes.

## VII. FIELD PERFORMANCE

Evaluation of field performance of heat recovery-water heating units is a difficult task and the results could vary considerably depending on variable weather conditions, and use patterns. The only available residential field test data is summarized in Table 3. Shown here are the claimed energy savings and the supporting field test data which was provided by the manufacturers.

### A. Case History

Location: Patrick Air Force Base, Florida

One thousand ECU units and 500 Weather King units have been installed on 2-5 ton heat pump units in military family housings. This represents the largest scale test to date.

Over a period of 1 year, these units have operated essentially with no trouble and with no significant differences in performance. Savings on water heating over a 9-month period are reported to be $16/month based on 3¢/kWh electric cost and 1200 ft$^2$ residential unit. These units were installed on unitary as well as split systems on heat pump units by Weather King, Florida Air, Bard, Carrier, and G.E. Heat recovery units have all had coaxial exchanger tubing but none with double wall.

Based upon their experiences they have specified the use of a separate storage tank for damping out rapid temperature cycling. Furthermore, at water feeding temperature of 140$^\circ$F from storage tank the electrical heater should be set at 120$^\circ$F. They also specify that the rise in compressor discharge head be less than 6 psi with no water flowing through the heat recovery unit. As for heat removal, only the super heat should be reclaimed in order to avoid the capillary expansion problem of slugging. Finally, a safety valve should be installed on the hot water tank with temperature setting at 210$^\circ$F and discharged to the outside.

### B. Operation Problems and Maintenance

There are basically two main problems with all of commercially available units; scaling and freezing. Scaling problem is unavoidable, since water flow, in both discrete flow design and semi-continuous flow design, is periodically stopped, enhancing scale formation. Removable ends on a heat exchanger provide a convenient means of cleaning the heat exchanger. In a non-removable end heat exchanger chemical cleaning is required. Insufficient data is available to specify cleaning frequency due to scaling. Freezing of water in the heat exchanger and connecting lines can be avoided by installing the heat recovery system indoors.

TABLE 3

RESIDENTIAL FIELD TEST DATA

| MANUFACTURER | A/C or H.P. CAPACITY | FIELD TEST DATA: Conducted by and/or location | Duration Months | No. of Units | kWh/month* saved or percent savings on water heating |
|---|---|---|---|---|---|
| Lynn-Aire | 3-ton G.E. H.P. | Electric Mem. Corp Douglas County, GA | 5 mo Apr - Aug | 1 | 590 |
| Lynn-Aire | 2.5 ton A/C | Georgia Tech | 3 hrs | 1 | — |
| Lynn-Aire | 3 ton A/C | Savannah Elec Pwr Co | 4 mo. Aug - Nov | 1 | 410 |
| Energy Conservation Unlimited, Inc. | 3 ton A/C | Georgia Power | 12 mo. | 4 | 46% |
| Lynn-Aire | 2.5 ton H.P. | Georgia Power | 12 mo. | 1 | 51% |
| Energy Conservation Unlimited Inc. | A/C | Alabama Power | 24 mo. | 8 | 50% |
| Energy Conservation Unlimited Inc. | 2.5 ton H.P. | Patrick AFB | 12 mo. | 1000 | 530 |
| Energy Conservation Unlimited Inc. | | Akron, Ohio | 6 mo. | — | 140 |
| Energy Conservation Unlimited Inc. | | Lakeland, Florida | 7 mo. | — | 500 |
| Sun-Econ | 4 ton carrier H.P. | Patrick AFB | 12 mo. | 500 | 530 |
| Hot Tap | 3.5 ton | Arizona Public Service | 12 mo. | 3 | 50% |

* Compressor savings not included

Because of the simplicity of design, heat recovery units have little operational problems and their maintenance is rather easy. Results of the test from installation of 1000 ECU units and 500 Weather King units in Patrick Air Force Base in Florida along with the results of tests by Alabama Power, Arizona Public Service, Florida Power, and Georgia Power indicate that these units in their present form have performed with little or no operational problems.

## VIII. COST EFFECTIVENESS

### A. System Design Selection

The aforementioned study by A. D. Little, Inc., on the economics of a heat recovery system with single tank water storage and dual tank system based on initial costs for new installation indicates that the economics of a single tank system appears to be more favorable. This was determined to be as a result of the increased surface-to-volume ratio of the dual tank system over the single tank system, resulting in greater standby loss.* In practice, however, the results of the field test data from Patrick Air Force Base on 1500 heat recovery units installed indicates the preference of the dual tank system. The additional tank is used for damping out rapid temperature cycling.

### B. Economics in Different Climate Zones

Based on an initial added cost of $300 for a heat recovery system, total electrical savings on water heating are used to obtain a payback period. Since total heat recovered is directly related to operating hours, regional annual operating hours of central air conditioners (Figure 4) were used to generate annual savings for different climate zones.

In the aforementioned study by A. D. Little, Inc., the single tank system was used in a computer model in different climate zones to generate potential savings and payback periods on heat recovery units.

The results of this analysis, forecast for year 1990, are presented in Table 4. Columns 1 through 3 are self-explanatory. In column 4, total annual point of use savings is combined water heating savings and compressor efficiency improvement savings for each zone. Column 5 refers to the annual BTU's saved from the installation of a heat recovery system at power plant. Using the payback periods presented in Table 4, which is only applied to central air conditioners, and appropriate modifications for heat pump installation, a simplified regional analysis is developed which justifies or rejects the installation of HRS on central air conditioners or heat pumps.

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*This may not be the case for a tank with greater insulation.

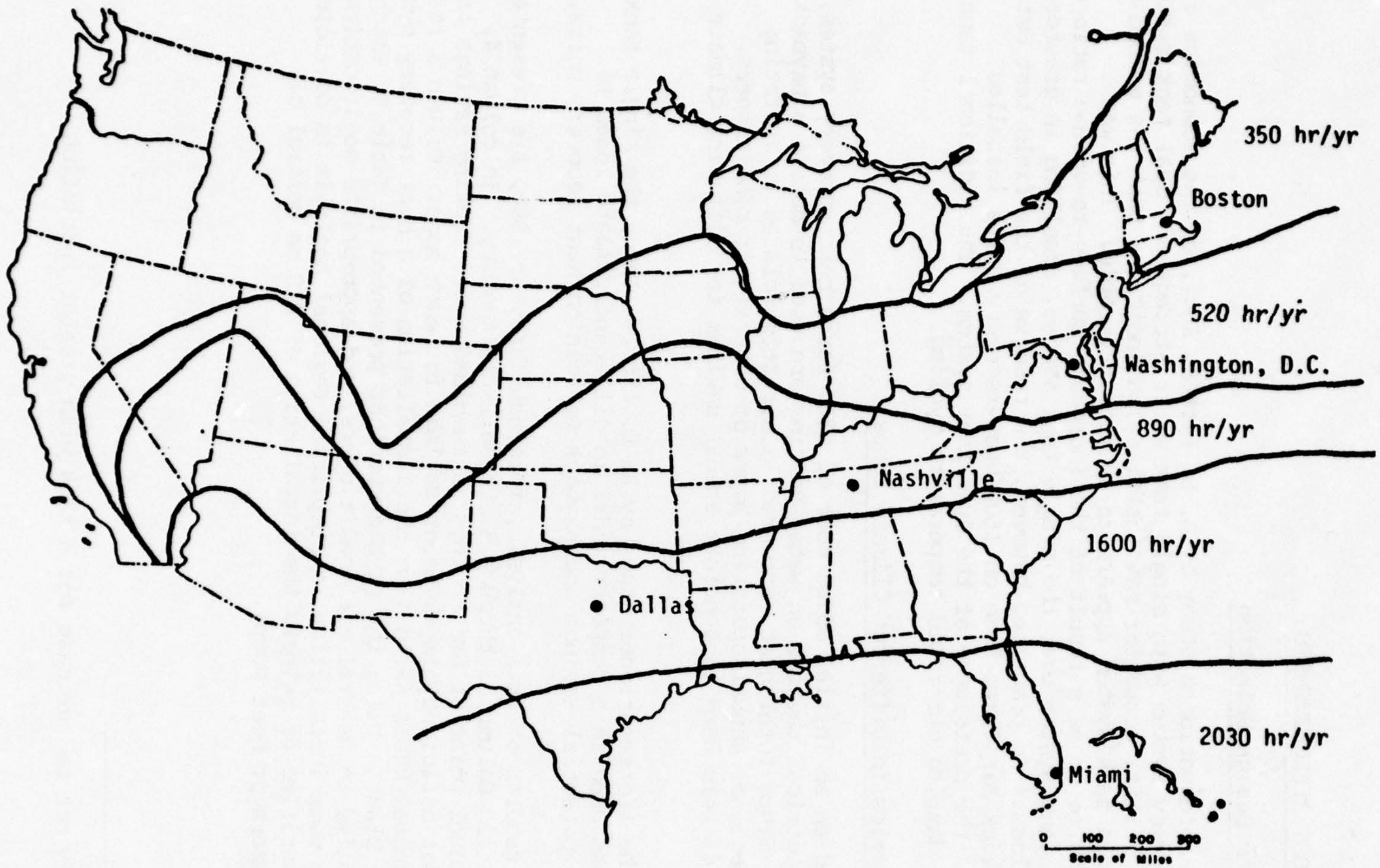


Figure 4. Annual Hours of Operation of Central Air Conditioners by region

## TABLE 4

A/C-HRS ENERGY SAVINGS IN DIFFERENT CLIMATIC ZONES-[1]
(Cooling Season Only)

BASIS: 3.5 Ton Air Conditioner

$.04 per kWh

| Zone Number | Representative City | Baseline Total Annual kWh A/C and Water Heating Without A/C HRS[3] | Cooling Compressor Hours | Annual Point of Use Savings (kWh/year) Total | A/C Portion | Annual Primary Savings (mm Btu/year) | Years to Payback (Added First Cost: $300) Electric Water Heating | Gas Water Heating[2] |
|---|---|---|---|---|---|---|---|---|
| 1 | Miami | 16,930 | 2,030 | 4,271 | 300 | 48.5 | 1.7 | 4.2 |
| 2 | Ft Worth | 15,230 | 1,700 | 3,067 | 100 | 34.9 | 2.4 | 7.6 |
| 3 | Nashville | 11,400 | 890 | 2,340 | 70 | 26.6 | 3.2 | 10.0 |
| 4 | Washington | 9,700 | 520 | 1,330 | 60 | 15.1 | 5.6 | 17.0 |
| 5 | Boston | 8,893 | 350 | 1,300 | 34 | 14.77 | 5.7 | 16.5 |
| 1990 Inventory Weighted Average | | 13,000 | | 2,538[3] | | 28.8 | 3.5 | 10.6 |

[1] Electric water heating is 7,260 kWh/year.

[2] Based on the same amount of water heated by air conditioner as the electric water heater plus the 25% credit for the gas recovery efficiency of 80%.

[3] Using heat pumps (heating and cooling), the annual savings could be raised to 4,200 kWh (65% increase), and the years to payback reduced to 1.8 (a 50% reductin). It is anticipated, though, that only one out of five air conditioners will be heat pumps in 1990.

Figure 4 is divided into three regions: Region 1 covering air conditioning use of 890 hr/yr and above (Nashville, Dallas, and Miami) appears to be a favorable region for installation of heat recovery-water heating units. Payback periods vary from 1.7 years to 3.2 years if installed on an air conditioner. Furthermore, payback periods can be significantly reduced if installed on a heat pump. Region 2 covering air conditioning use of 520 hr/yr (Washington, DC) has a questionable economics. Annual savings are to be calculated from the following equation:

Amount savings = A x B x C x D x E where:

$$A = \frac{\text{BTU Savings}}{\text{Ton-hr A/C}}$$

B = electricity cost, $/kwh

C = 0.000293 kwh/Btu

D = Location Factor, Figure 3, A/C hours/yr

E = A/C capacity*

Assumptions: Central A/C
Electrical water heating
Total usage of hot water

Finally, payback period should be estimated from the initial cost, including installation, and annual savings. Typical installation time, based upon the experience of Arizona Public Service Company, is 4 to 6 man hours.

If used with a heat pump, the payback period is reduced but field test data is insufficient to confirm the 50% reduction in payback period cited in Table 4 by A. D. Little. Region 3 covering air conditioning use of less than 500 hr/yr does not appear to have a favorable economics for installation of heat recovery units on central air conditioners. Installations on heat pumps are questionable since economics are dependent on the coefficient of performance of the heat pump, and environmental conditions for various locations in this zone.

Further field test data on installation of heat recovery-water heating units on heat pumps are required in order to clarify the economics.

*1 to 25% compressor efficiency improvements are not included as a conservative measure.

## IX. CURRENT AND FUTURE TESTING AND DEMONSTRATION

Reports from Division of Building and Community System of ERDA, Consumer Products & Technology Branch of ERDA, Office of Energy Conservation of NBS, Center for Building Technology of NBS, Department of Energy and the Federal Trade Commission, indicate that a number of tests are being conducted on heat recovery-water heating units. Standards are being developed which would specify installation codes, labeling, safety requirements, and warranty. The Department of Energy and National Bureau of Standards are currently jointly involved in developing test methodology and evaluating energy recovery on the heat recovery-water heating systems manufactured by ECU, Carrier, Marvair, Sun-Eon and Lynn Aire. This program, under the direction of Dr. Don Walukus (DOE-ORNL) and Dr. Andy Fowell (NBS) will be completed around mid-year 1979. In addition EPRI is currently sponsoring follow-on work by Mr. Richard Merriam of A. D. Little and installation of heat recovery units in southern brewery refrigeration systems. The above tests should establish standard test procedures for rating and specifying heat recovery units. Also these works should establish optimized refrigeration unit control, optimized sizing of the HRS, and the effect of the HRS when used with a heat pump in the northern United States. Figure 5 presents A. D. Little's forecast of the growth of these units with and without support of DOE.

To date, federal and state regulations do not allow manufacturers to claim the energy savings of the HRS as part of the air conditioner energy efficiency. This policy hinders commercialization and should be reconsidered.

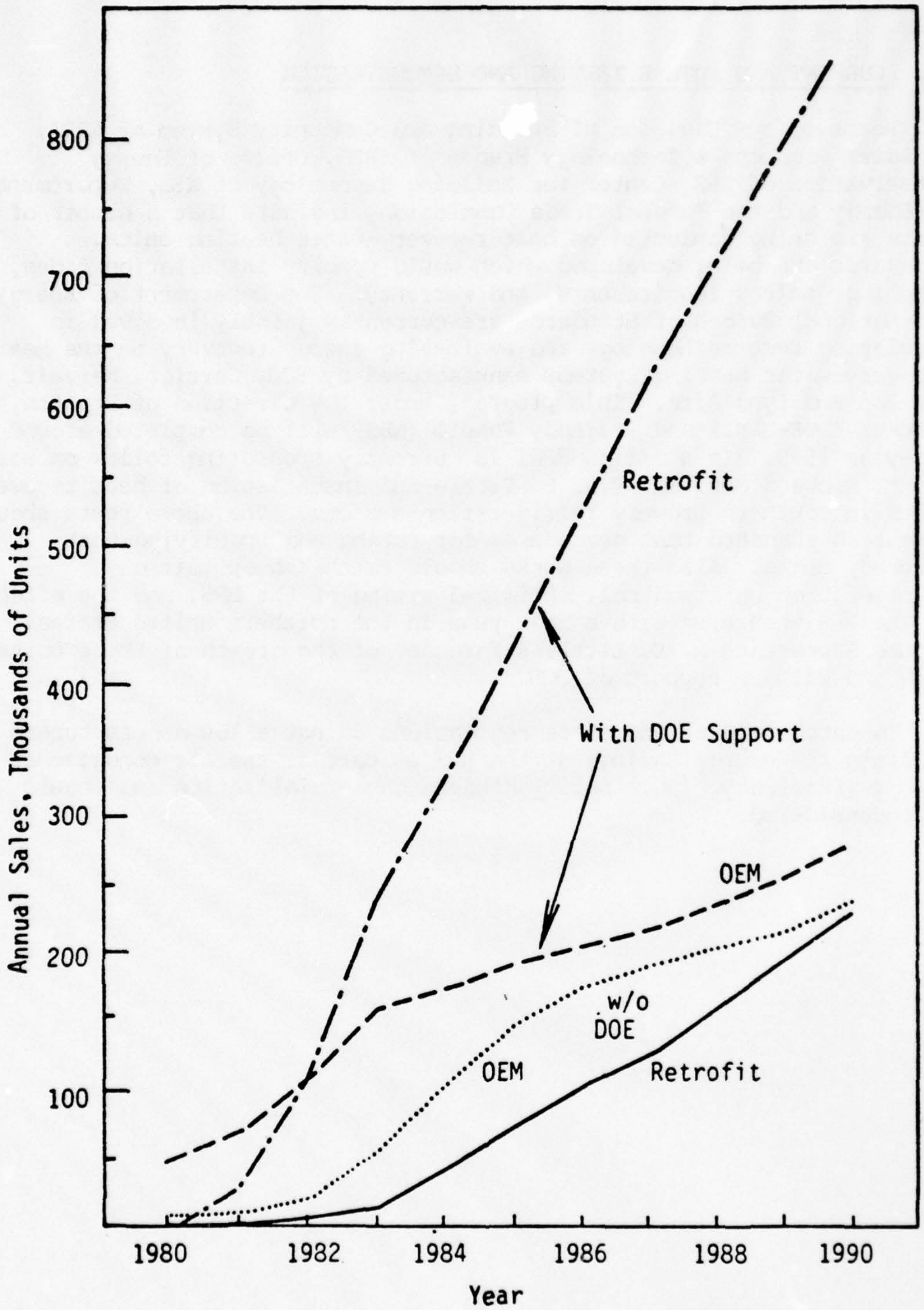


Figure 5. Projected Sales of OEM and Retrofits A/C - HRS
With and Without DOE Support

## X. SAFETY

Basic concerns in safety are due to either electrical shortage in the unit or a possiblity of a potable water contamination from freon and compressor oil due to a complete exchanger integrity failure.

In the former case, approval by Applied Research Laboratories and compliance with local electrical codes are sufficient for safe operation.

In the latter case studies by Dr. Gibson, of duPont, Drs. Miller and Cowsan of Southern Research Institute, and Sun Petroleum Products Co., indicate that neither the freon nor compressor oil leak (either fresh or burned oil) cause any health problems when leaked into water in a heat recovery-water heating system. Further testing by the Holman/Pyle Company has concluded that microrganisms cannot live in a Freon 22 system and so the danger of contamination is reduced. The Underwriter Laboratory Standard for coil design SA1287 has been used with the Heat Exchanger.

## XI. PRODUCT WARRANTY

All presently available heat recovery units are covered for a period of one year by respective manufacturers. Furthermore, no major manufacturers of air conditioners and heat pumps will void their warranty on their units if it is retrofitted with a heat recovery unit as long as it is installed by a qualified technician according to the instructions set forth by the manufacturer of the heat recovery unit.

## XII. STATE AND CITY PRODUCT APPROVAL

It should be noted that installation of heat recovery-water heating units is subject to the approval of the local departments of Health and Social Services, Building and Zoning, Safety and Permits, Electric and Water Utilities, and Insurance. A number of the manufacturers of heat recovery units have presently received installation approvals from many local ordinances. Installation in each area should be checked for local approval through the manufacturers.

## XIII. CONCLUSIONS

The following conclusions are made based upon this study:

1. The heat recovery system (HRS) does save energy and has a reasonable payback period. It has proved to be simple and trouble free. The number of HRS will continue to grow and may be incorporated as part of normal heat pumps or air conditioners in the near future.

2. Insufficient test data are available to indicate which unit performs better than others, so within optimized equipment guidelines, selection must be based upon economics and availability. HRS rating standards are being determined and comparisons should be available within 2 years.

3. A method is available (described herein) to determine if the unit is economical for each region of the country. Heat pumps operating above the balance point provide better payback than air conditioners using HRS, but insufficient test data are available to quantify the advantage due to the use of a heat pump. For gas water heating, in most cases, the HRS is not justified at this time.

4. Local municipal or state codes should be checked before installation of these units. Toxicity due to Freon 22 or compressor oil is not a problem so safety may be determined through standard testing procedures by Applied Research Laboratories, Underwriters Laboratories, etc., for each unit.

5. All commercial HRS units have 1-year warranty. Insufficient field test data are available to determine longevity. No commercial manufacturer of air conditioners or heat pumps will void their warranty with the installation of an HRS; however, the individual manufacturer should be contacted to determine specific installation instructions.

## XIV. RECOMMENDATIONS

Based upon this work the following recommendation is made:

That this report be used only during the interim period until DOE and NBS complete work on comparison and standard generation methods. The DOE-NBS work should be followed closely and their results should be incorporated into any judgements concerning economics or relative merits of the commercial units. No further work should be done until the results of the NBS-DOE tests are known.

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Addendum to

"Performance Evaluation of Concepts and Devices for Heat Reclamation from Air Conditioners, Heat Pumps, and Refrigeration Equipment"

## The Colloid-A-Tron and The Condenser Spray Unit

The Colloid-A-Tron is a device which controls scale precipitation by influencing the size, shape and place of its formation. The Colloid-A-Tron consists of a metallic core inserted into the water stream. It is fashioned by an alloy of copper, zinc, nickel and tin. The core's configuration creates a turbulent water flow that produces an electro-chemical reaction which generates a collodial suspension from mineral ions in water. The colloids are kept suspended in the moving stream of water and don't deposit as scale. This unit, in use since 1969, is patented and manufactured by Century III Corporation, Tucson, Arizona.

The Colloid-A-Tron is effectively used in conjunction with the Condenser Spray Unit (CSU) for saving energy in air conditioners. The CSU works by spraying water on the condenser coils during each on-cycle of the compressor. This spray over the condenser lowers the refrigerant temperature exiting from the coils which causes an improved compressor efficiency. No heat is reclaimed in this unit. The Colloid-A-Tron is used for minimizing scale deposition on the consenser coils.

The Condenser Spray Unit has been marketed since May of 1977, although its test models date back to early 1976. The presently available models of CSU are CSU 3000 and 4000; the former is recommended for use with a 3-ton to 7.5-ton system (or 15 tons split systems with two compressors), while the latter is designed for A/C units up to 15 tons or split systems up to 30 tons.

## Energy Saving Economics

To date no test data other than the ones conducted by the manufacturer are available. The manufacturer saving claim of 30%, based on a vendor test which was witnessed by the Tucson Gas & Electric Company, appears to be valid. Based on this figure it appears that the unit can save about 1/2 to 3/4 of the energy saved by a heat recovery water heating unit depending upon the section of the country. Since the installed cost for CSU, (about $400), is comparable to a HWRS unit, the pay-out period for CSU would be 1.3 to 2.0 times as long as that for a HWRS unit.

Using the A. D. Little model of heat recovery systems along with the results of the tests provided by the manufacturer, it appears that up to 6 times the water usage recommended by the CSU vendor will be required.

Warranty

No A/C manufacturer has approved or endorsed the CSU for installation on their unit at the present time. However, marketing research by Century III Corporation indicates that 95% of A/C in use are no longer under warranty.

Operation, Longevity and Code Compliance

The only operational problems inherent with the CSU appears to be a tendency toward slugging; however, the manufacturer adjusts the refrigerant charge to eliminate this problem. A long-term test (>2 yrs.) would be necessary to determine if scaling is a problem. No information was obtained on code compliance.

Conclusions: While no direct test comparisons are available between the CSU and HWRS Systems, preliminary results indicate the following:

1. The CSU unit can save an appreciable amount of energy in air conditioners; however, the energy is not reclaimed in the form of water heating.
2. Pay-out periods on the CSU unit may be from 1.3 to 2.0 times as long as for the HWRS, based upon limited test data for the CSU and extensive test data for the HWRS.
3. Test data for the CSU are so limited that longevity, operational problems and maintenance are uncertain. Furthermore, the possibility of warranty jeopardization is present with the CSU, but does not exist with the HWRS unit.
4. Safety is not a consideration with the CSU unit.

Recommendation: Based upon this study the following recommendations are made:

1. That a direct comparison of the CSU be made to the HWRS System. The most likely place for this to occur is in the current NBS-DOE study mentioned in the main report.
2. That until such tests are made, the HWRS be given preference over the CSU unit.

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